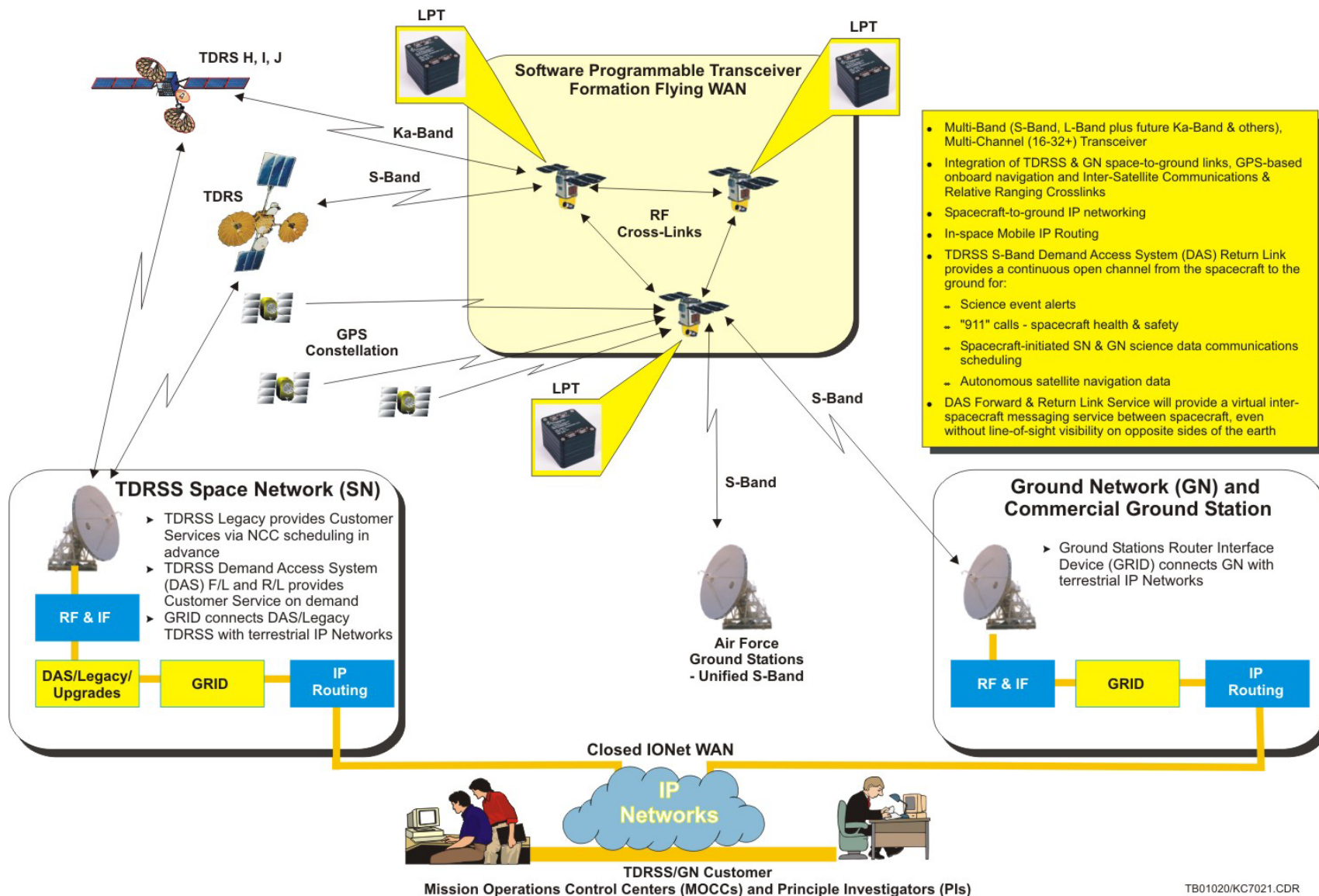


**GSFC/SOMO Technology Development Program  
Annual Review**

**Advanced Space and Ground Networks  
Work Area 5630**

**September 19, 2001**

**Dave Israel/Code 567**

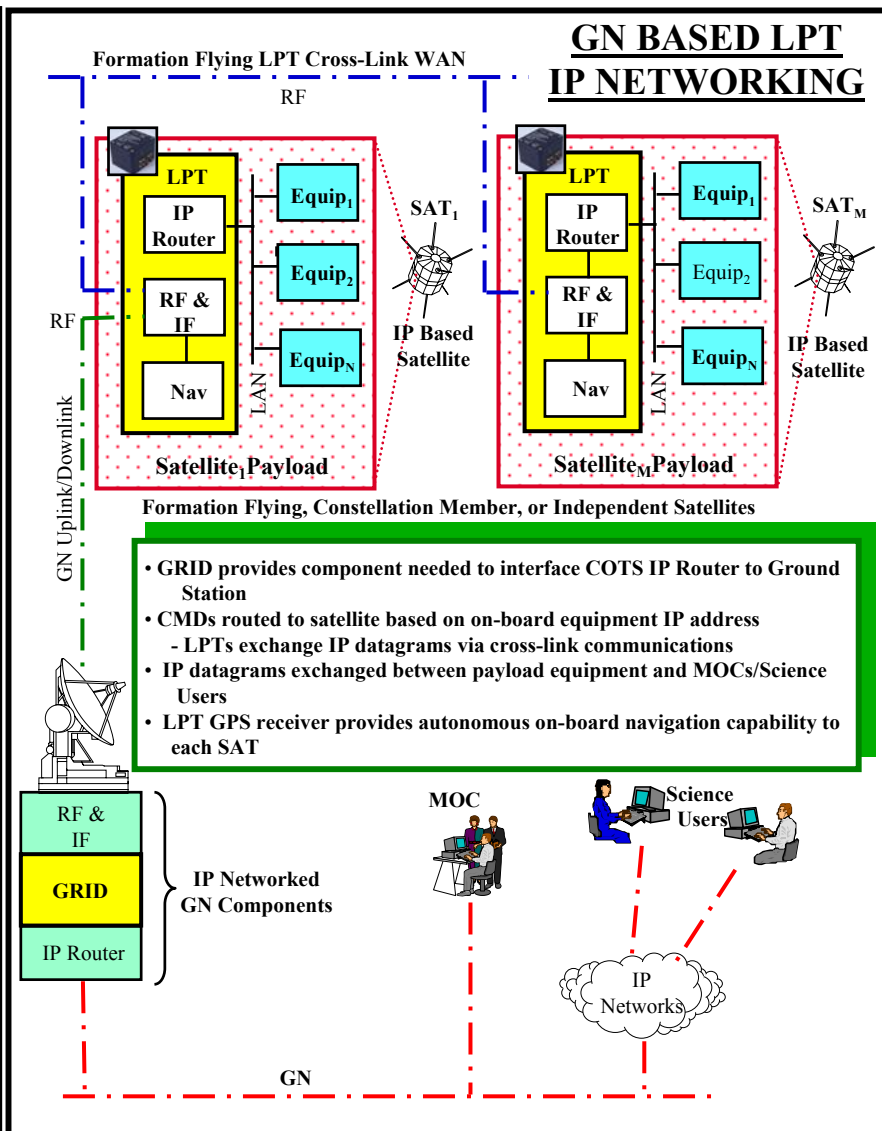
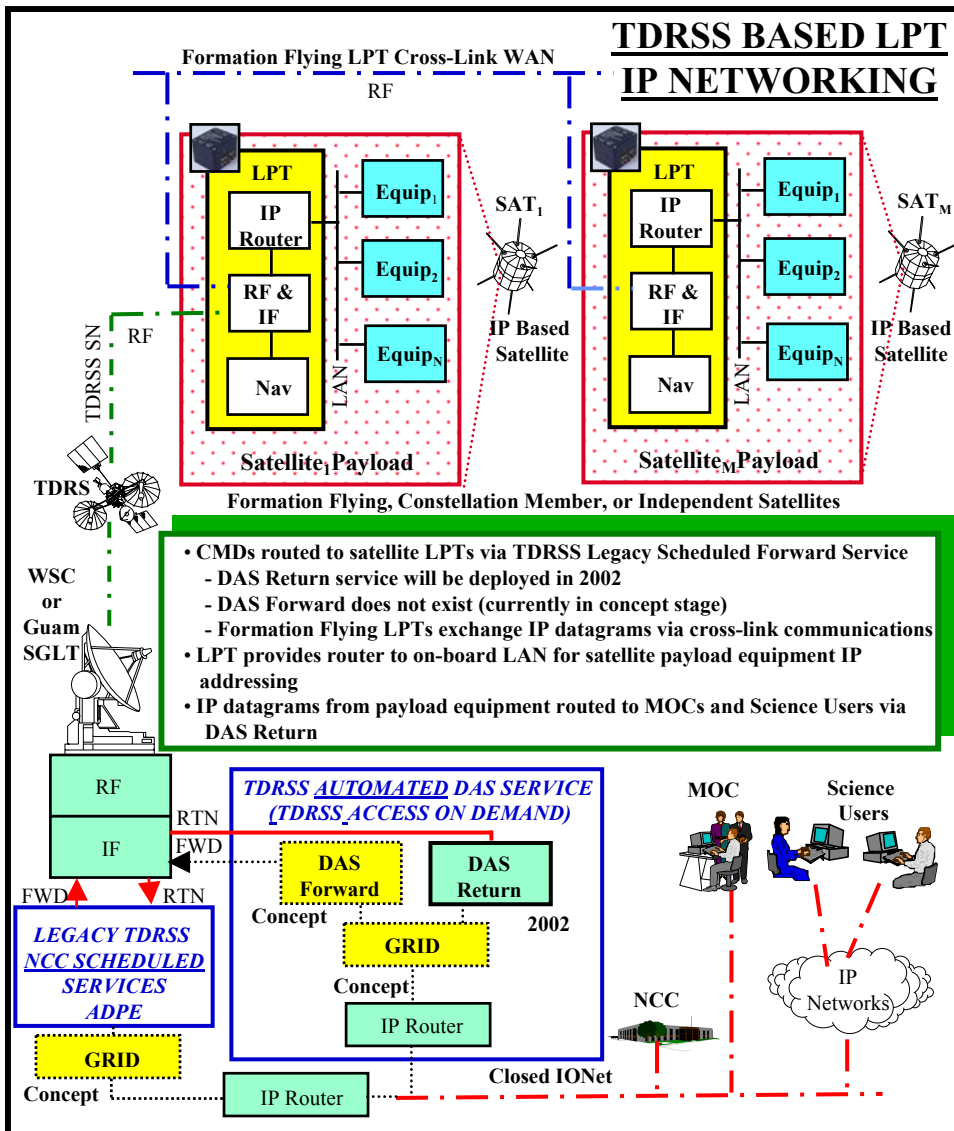


**Advanced Space and Ground Networks Work Area  
GSFC/SOMO Technology Development Program  
Annual Review**

**Tracking & Data Acquisition Future Systems  
Applications  
Task 5631**

**September 19, 2001**

**Dave Israel/Code 567**



# Tracking & Data Acquisition Future Systems Applications

## Overview of Task Objectives

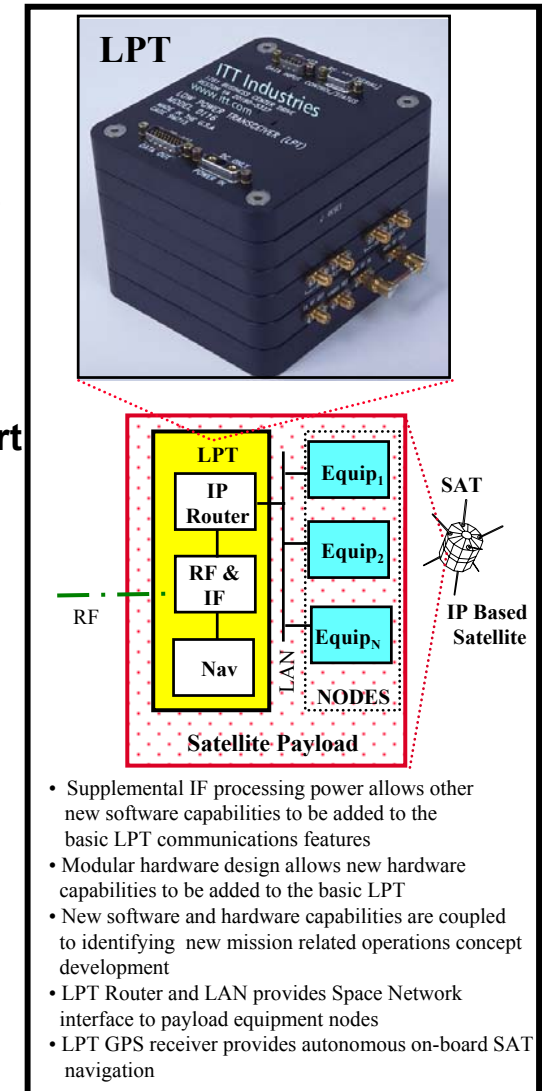
- **High-Level Task Objective**
  - Develop and demonstrate future near-earth space communications operations concepts and support next generation customers through the definition of technology
- **Detailed Objectives Grouped by Component Tasks:**
  - **Software Programmable Transceivers Operations Concept Task**
    - » Produce operations concepts, hardware designs and demonstrations for autonomous and low power operations using reconfigurable software programmable transceivers
  - **Networked and Crosslink User Operations Concept Task**
    - » Produce concepts and demonstrations for networked formation flying users within the context of crosslink and TDRSS SN and GN mobile IP end-to-end operations
  - **Ground Station Router Interface Device (GRID) Task**
    - » Produce a prototype device capable of connecting a standard router serial port to standard ground station interfaces. This capability will enable direct IP communications with users.

# Tracking & Data Acquisition Future Systems Applications

## Overview of Software Programmable Transceivers

### Operations Task Objectives

- **Develop Software Programmable Transceivers Operations Concepts**
  - Identify future mission software based capabilities that are amenable to implementation within the limits of the reserve processing throughput that accompanies the technological improvements associated with the generational series of Software Programmable Transceivers including the Low Power Transceiver (LPT)
  - Identify future missions hardware requirements that support the operations of the augmented software functions within the context of the the technological improvements associated with the generational series of LPTs
  - Develop operations concepts that support future missions based software functionality
- **Develop Demonstration Plans**
  - Produce demonstration plans that support the increased software capabilities of radios within the context of future mission operations scenarios



# Tracking & Data Acquisition Future Systems Applications

## Overview of Networked and Crosslink User Operations

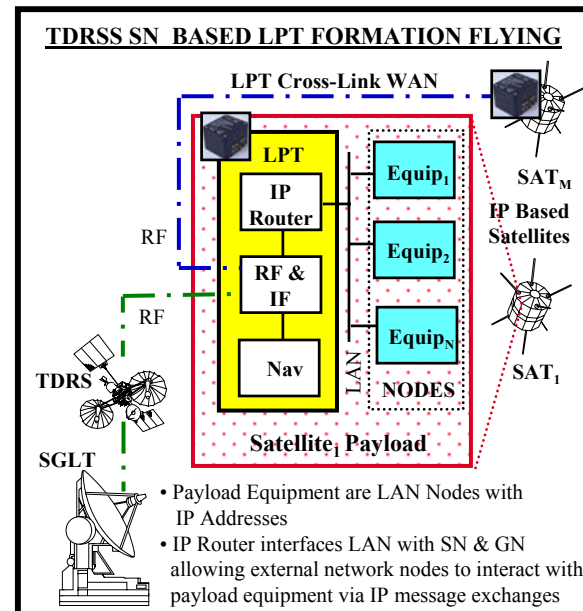
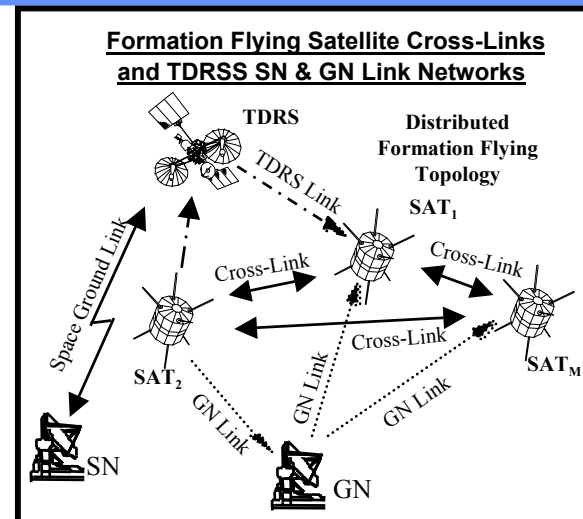
### Task Objectives

- **Develop Networked & Crosslink Operations Concepts**

- Participate in the Intersatellite Communications Working Group (NASA HQ & GSFC Codes 450/560/570/580/Industry) to:
  - » Develop crosslink operations concepts and white papers to support mission developers
  - » Develop standards, as necessary, to increase availability and interoperability of hardware
- Prepare Near-Earth Space Network (SN) and Ground Network (GN) Internet Protocol (IP) Based Operations Concepts Document Work
- Conduct analyses and simulations, as necessary, to assess performance of operations and protocols (e.g., Mobile IP) within the context of different formation flying topologies and communications strategies

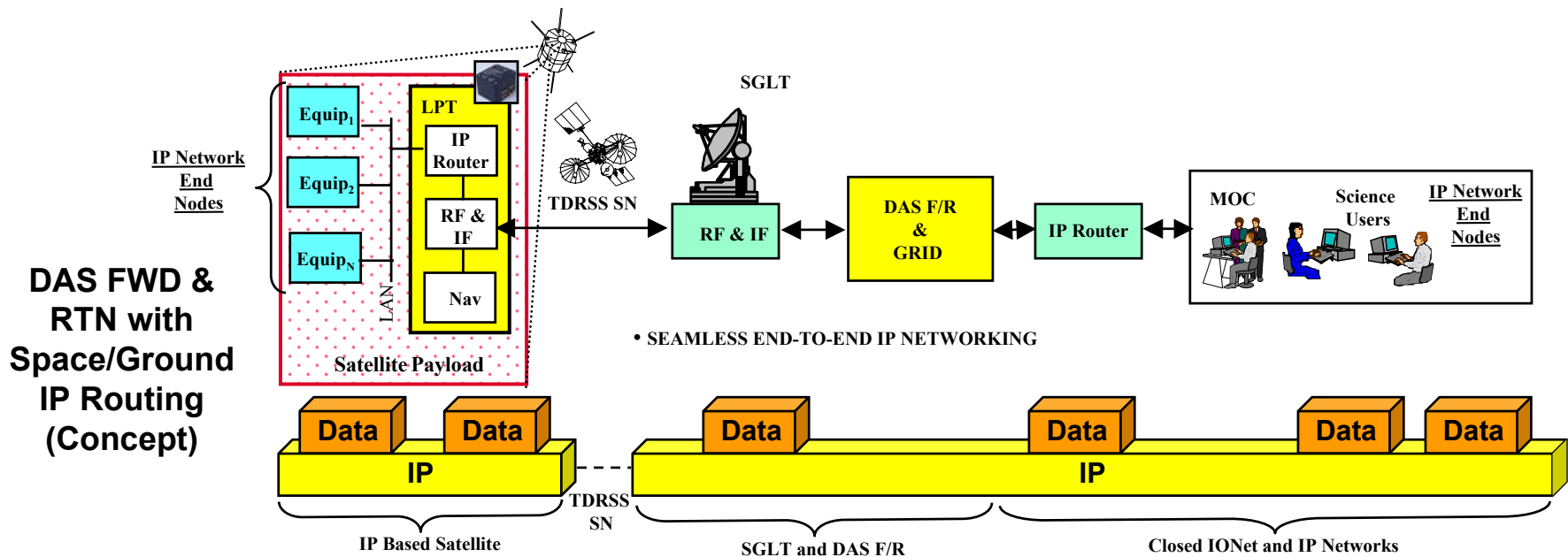
- **Develop Networked Demonstration Plans**

- Produce plans and conduct demonstrations to show the feasibility of simple formation flying networked communications strategies



# Tracking & Data Acquisition Future Systems Applications

## TDRSS DAS Based IP Networking Objective

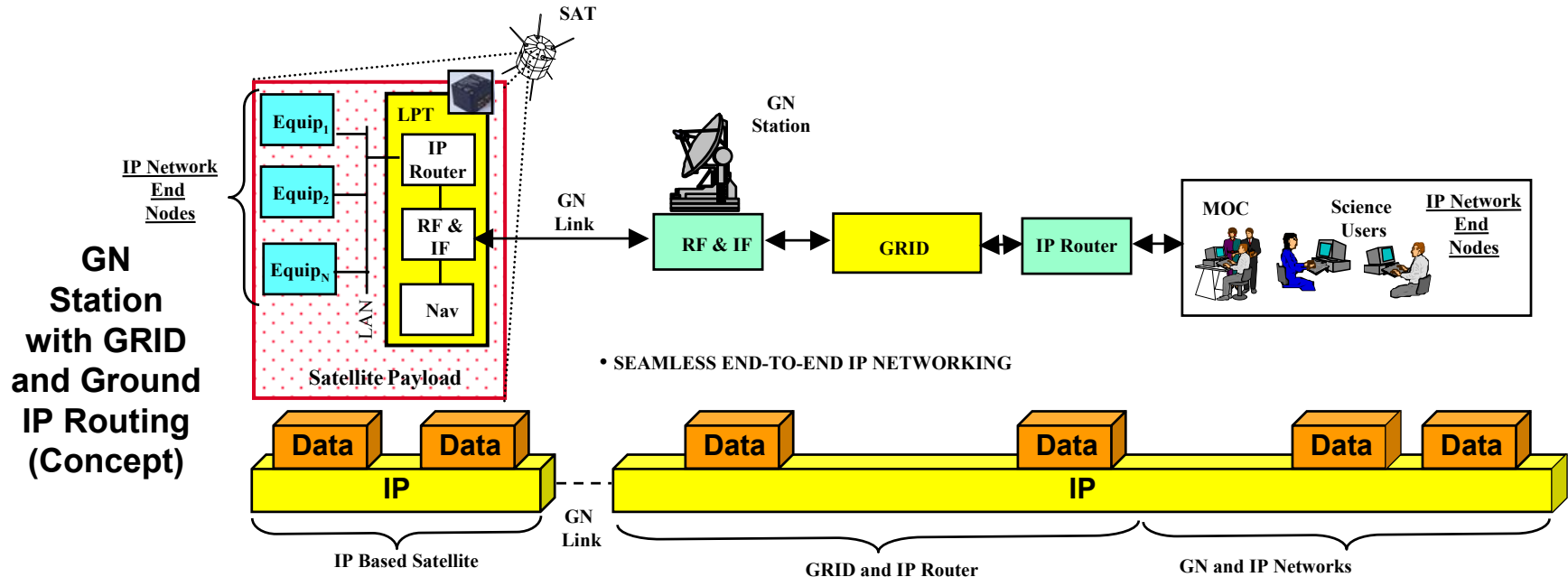




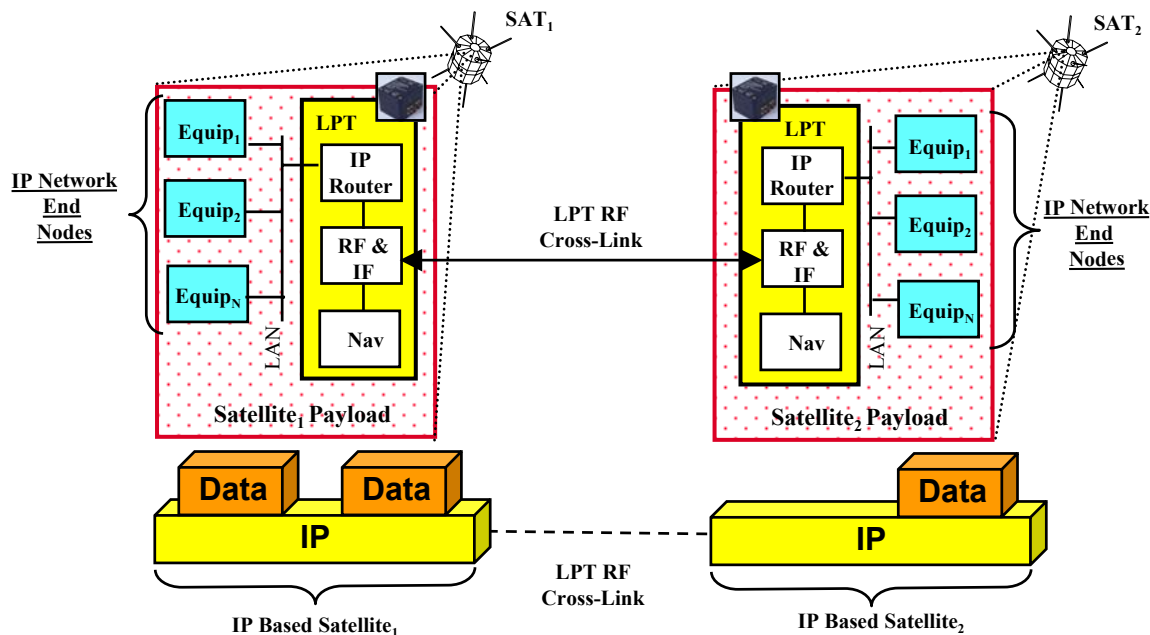
# Tracking & Data Acquisition Future Systems Applications

## GN Based IP Networking Objective

### GN Two-Way Spacecraft-to-Customer IP Communications



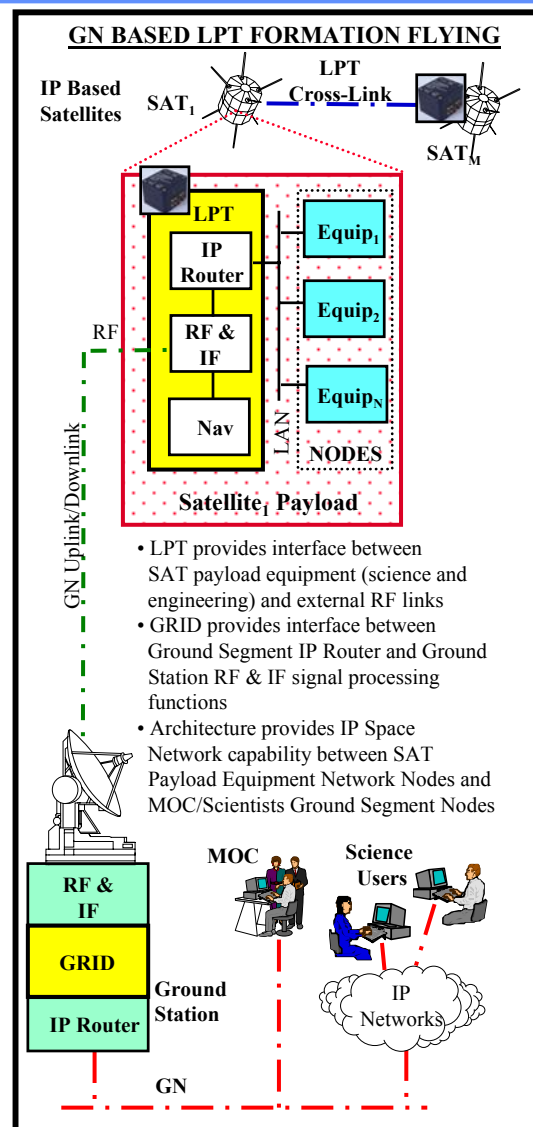
### Formation Flying Two-Way Spacecraft-to-Spacecraft IP Communications



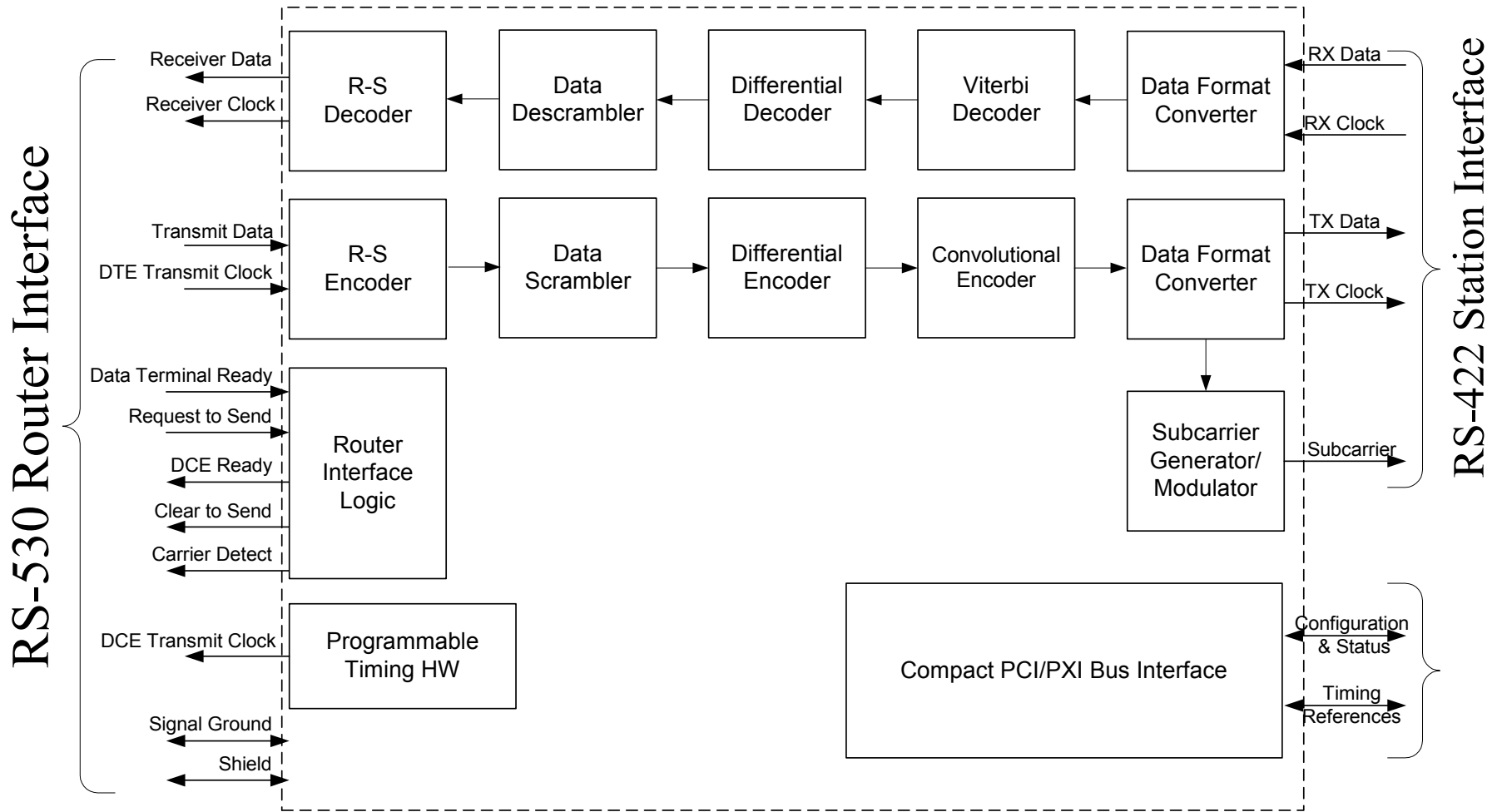
## Overview of GRID Task Objectives

Produce a prototype device capable of connecting a standard router serial port to standard ground station interfaces. This capability will enable direct IP communications with users. GRID will provide all necessary handshaking and clock signals to the router and perform any required channel coding and decoding for the RF link.

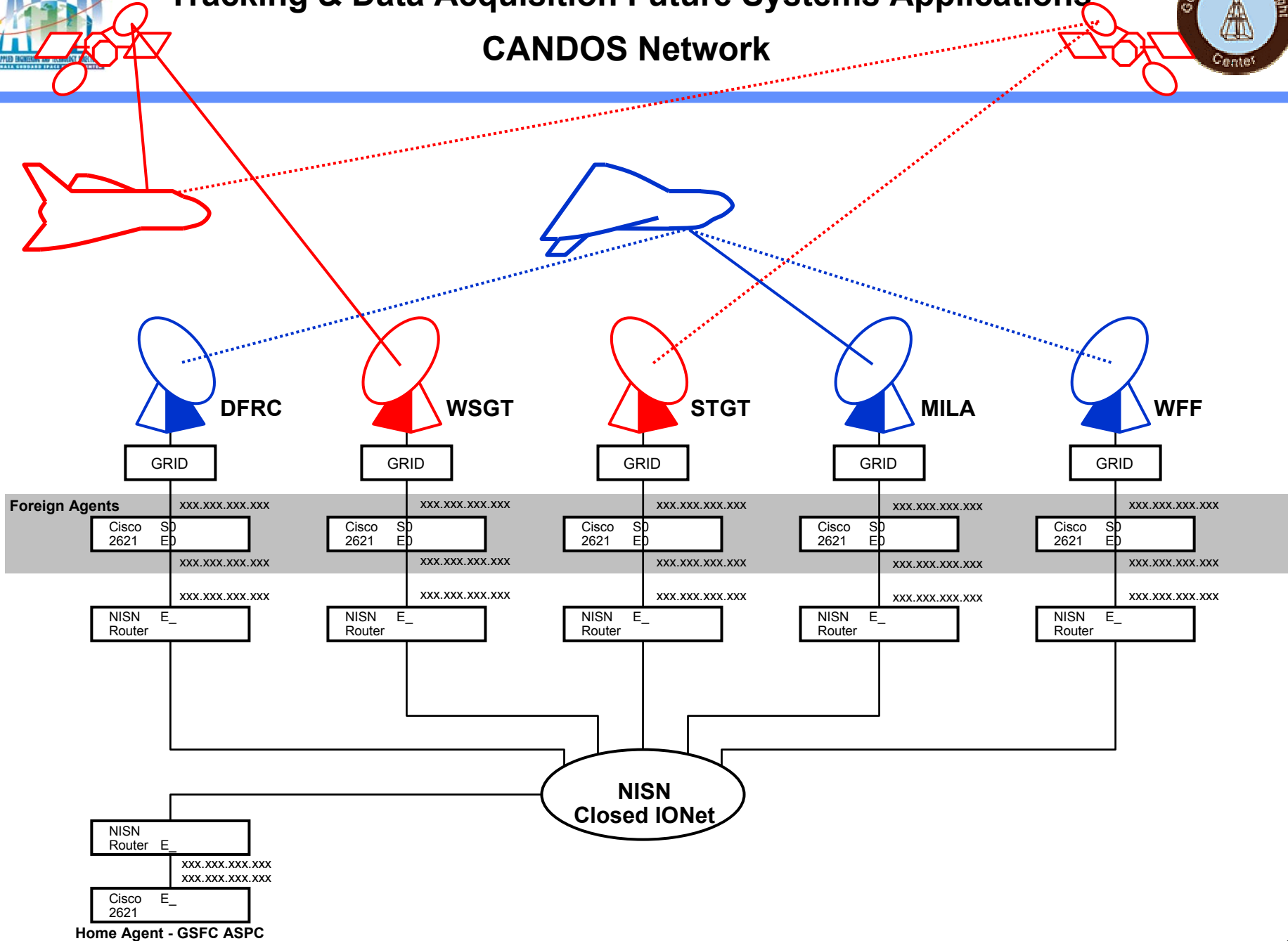
- Develop GRID Requirements
- Design GRID Prototype (collaboration with 564)
  - Complete first prototype by December 2001
- Test GRID
  - Test prototype first with GSFC Code 588 OMNI Flatsat Test Bed
  - Test prototype with Ground stations
- GRID to be used to support CANDOS flight (June '02)
- Transfer GRID technology to Industry



## GRID Channel Card (GCC)



## CANDOS Network



# **Tracking & Data Acquisition Future Systems Applications**

## **Task Work Completed Since March 2001**

- **Continued preparing Draft Software Programmable Transceiver Operations Concepts Document**
- **Continued preparing Near-Earth Space Network (SN) and Ground Network (GN) Internet Protocol (IP) Based Operations Concepts Document**
- **Supported Inter-Satellite Crosslink Working Group (Code 560 and 570 Co-Leading Current Activities)**
  - **Developed Draft Inter-Satellite Crosslink Considerations White Paper**
  - **Obtained Integrated Mission Design Center (IMDC), GSFC Code 740, Recognition for White Paper to Support IMDC Operations**
- **Developed GRID Requirements and Design**
- **Continued testing GRID Prototype circuits**
- **Developing GRID Channel Card integrated schematic**

# **Tracking & Data Acquisition Future Systems Applications**

## **Task Work to be Completed by September 2001**

- **Interim Version of Software Programmable Transceiver Operations Concepts Document**
  - **Generic Software Programmable Transceiver Operations Concept that Includes the Incorporation of Augmented Transceiver Capabilities**
    - » **IP Network Management**
    - » **GPS and Traditional Navigation Management**
    - » **Communications Resource Scheduling Management**
    - » **Transceiver Software Reconfiguration via Remote Control**
  - **Future Missions that can Benefit from the Operations Concepts**
  - **Formation Flying Operations Scenarios**
  - **LPT is a Specific Example of One Implementation of These Capabilities**
- **Interim Version of Near-Earth Space Network (SN) and Ground Network (GN) Internet Protocol (IP) Based Operations Concepts Document**
  - **SN and GN Infrastructure Capabilities needed to Support End-to-End IP Mobile IP Networking Operations**
  - **Software Programmable Transceiver Serves as One IP Node Attached to SN or GN**
  - **Future Missions that can Benefit from the Operations Concepts**
  - **Scenarios Involving S/C-to-S/C SN IP Based Operations**

Task	FY01				FY02				FY03			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
<ul style="list-style-type: none"> <li>• Near-Earth SN and GN IP Based Operations Concept Document</li> <li>• Software Programmable Transceiver Operations Concept Document</li> <li>• Inter-Satellite Crosslink Working Group Support</li> <li>• SN &amp; GN IP Operations Requirements Analysis Document</li> <li>• Software Programmable Transceiver Requirements Analysis Document</li> <li>• GRID</li> </ul>				Interim ▽				Final ▽				
				Interim ▽				Final ▽				
				Draft White Paper ▽		White Paper v1.0 ▽			Draft Technology Plan/Standard ▽			
								Draft ▽				Final ▽
									Draft ▽			Final ▽
						Prototype ▽	CANDOS ▽		Tech Transfer ▽			



**Advanced Space and Ground Networks Work Area  
GSFC/SOMO Technology Development Program  
Annual Review**

**Ka-band Utilization and Technology Studies  
Task 5632**

**September 19, 2001**

**Dave Israel/Code 567**

# Tracking & Data Acquisition Future Systems Applications

## Program Overview

- **The Ka-band Utilization and Technology Study is a series of coordinated development, validation, and insertion efforts intended to provide advanced Ka-band communications solutions for future near-Earth missions**
  - **Save time and cost for missions performing Ka-band communications system architecture tradeoff studies**
  - **Simplify system development using existing COTS and GOTS products**
  - **Promote information exchange btwn Ka-band equipment users and developers**
  - **Encompass requirements of SN and GN users**
  - **Various data rates considered including high rate, BW constrained SN users**
- **The objective of the Study is to cost-effectively advance the evolution of Ka-band communications systems and components for the NASA user community by leveraging existing commercial products and NASA, industry, academic, and foreign space agency R&D projects with selected new technology analysis, systems engineering, and transition support efforts**
- **Studies support NASA Strategic Mission Objectives by promoting validation of Ka-band technologies and operations concept and selection of bandwidth efficient modulation / coding formats to ensure efficient use of SN and GN resources**

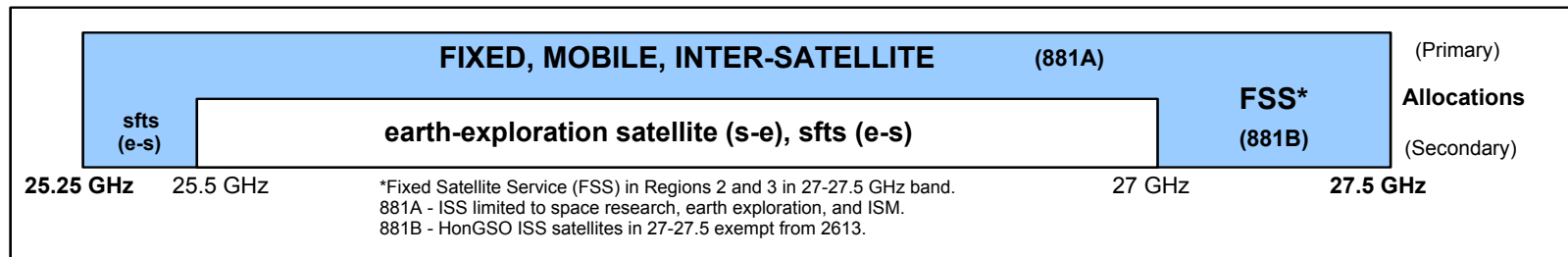
- The primary driving requirement for the development of Ka-band communications systems is based upon the inadequacy of other available frequency allocations to support future NASA high rate mission requirements:
- The X-band 8025 - 8400 MHz Earth Exploration Science SGL allocation is increasingly congested and insufficient for rates above 300 Msps using traditional modulation techniques
  - Particular impact to polar-orbiting EOS-type missions
- Ku-band SN link (225 MHz TDRS KuSAR service) is problematic due to loss of primary status for the associated forward link frequency (13.75 – 14.0 GHz) Space Research Service allocation

Future High Rate NASA Missions

Mission Name	Est. Start Date	Orbit	Approximate Data Rate
Current EOS Missions	2000	LEO	150 Mbps
Earth Observing (EO) Series	2000 – 2003+	LEO	105 – 300 Mbps
NPP	2005	LEO	300 Mbps
NPOESS	2007	LEO	300 Mbps
Future EOS (or similar) Missions <sup>(2)</sup>	2001 - 2015	LEO	300 – 800 Mbps
SAR Series <sup>(2)</sup>	2008	LEO	> 1 Gbps
(2) Assumed			

- **The benefits of Ka-band communications for NASA missions include:**
  - Supports higher data rates due to larger Earth Exploration Satellite primary allocated bandwidth (1.5 GHz) and TDRS H,I,J KaSAR Wideband Return Channel
  - Allows smaller, lighter spacecraft components (e.g. Antennas)
  - No spectrum congestion or interference among users
  - Greater flexibility due to overlapping SSL / SGL frequency allocations
  - No plans for channelization
  - Etc.

### *Overlapping Ka-band SSL / SGL Frequency Allocations*



# **Tracking & Data Acquisition Future Systems Applications**

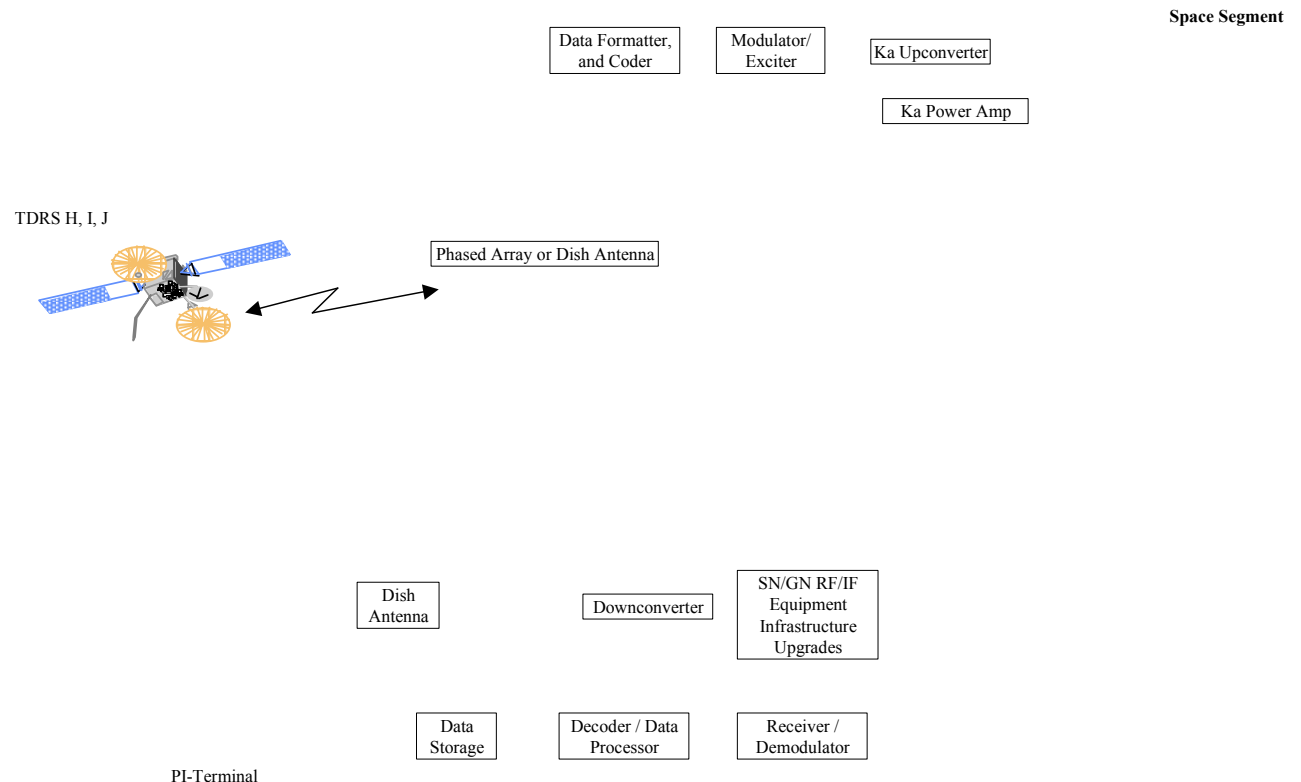
## **Ongoing and Completed Activities**

- **The Ka-band Utilization and Technology Study consists of a number of inter-related systems engineering, technology survey, analysis, and simulation tasks**
- **Products include:**
  - **Near-Earth Ka-band communications architecture concepts suitable for future NASA missions**
  - **Technology alternatives for the KaTP high rate testing activity**
  - **Detailed evaluations of advanced BW Efficient Modulation and Coding techniques presented at international conferences and input to the GSFC standards community for CCSDS recommendation development**
  - **WWW Ka-band component technology WWW-accessible database**

# Near-Earth Ka-Band Communications Architecture Development

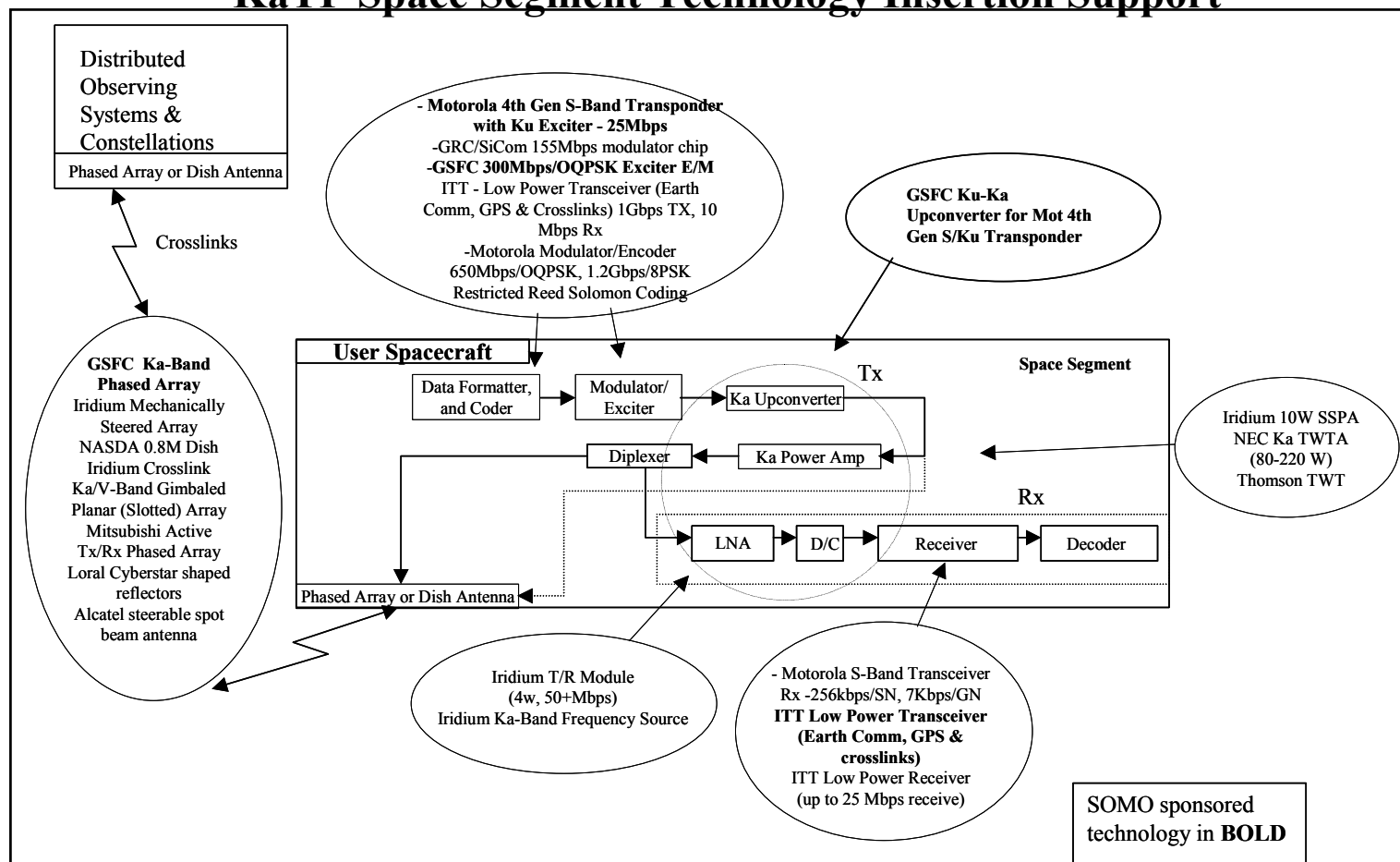
- Developed high level design concepts for near-Earth Ka-band communications systems
- Top-level designs included definition of required characteristics for key components and identification of existing COTS candidate products
- Also evaluated applicability of ongoing technology developments within GSFC and other NASA centers
- Concept served as input in formulation of technology development roadmaps

Near-Earth Ka-band Reference Architecture



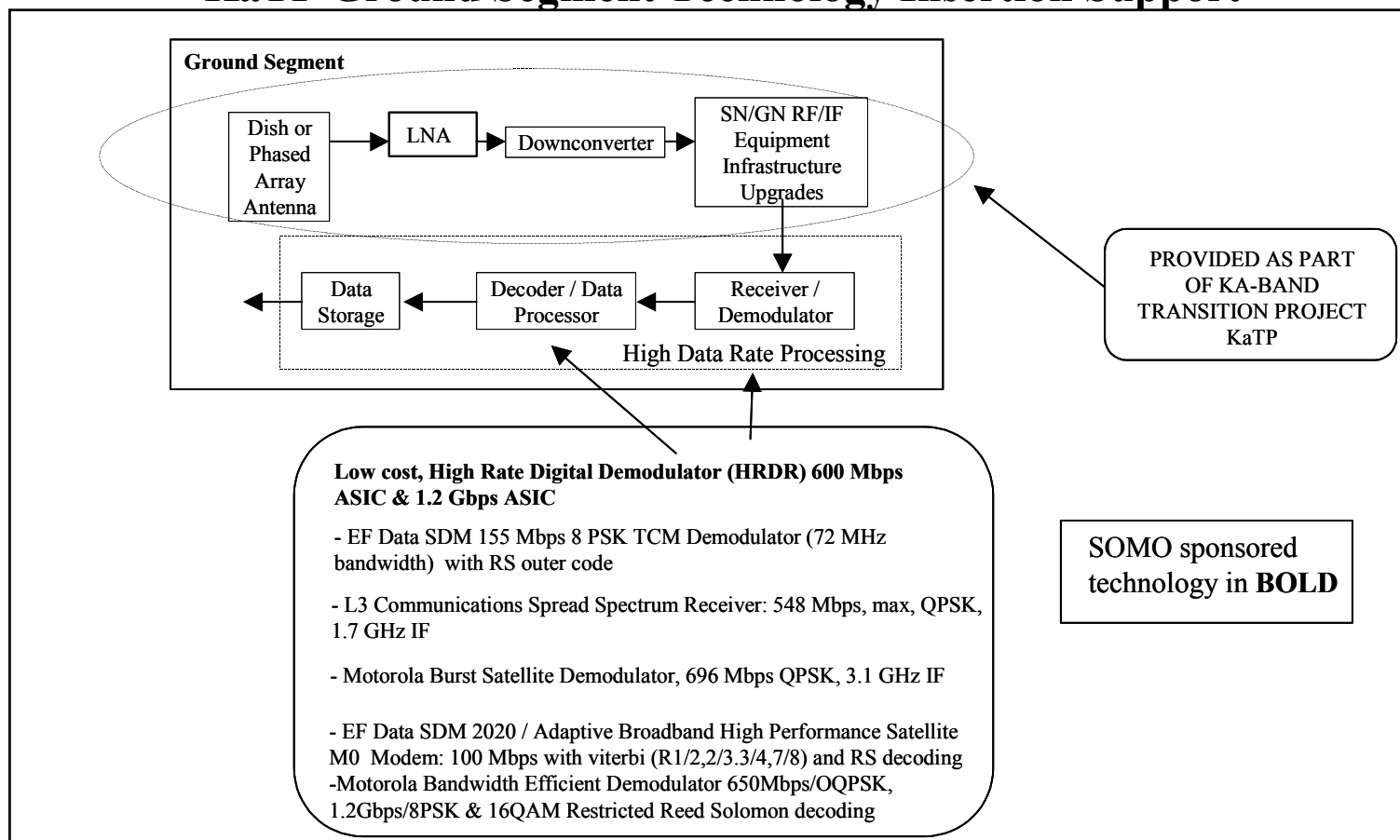
- **Technology Insertion Support for the Ka-band Transition Project includes:**
  - Performed investigation and analysis of existing and developmental component technology options for planned SN / GN ground segment upgrades

### KaTP Space Segment Technology Insertion Support



- Activities under the KaTP Technology Insertion Subtask include:
  - Developed KaTP demonstration alternatives and examined available space segment components
  - Developed an RFI to request additional information for applicable component technologies

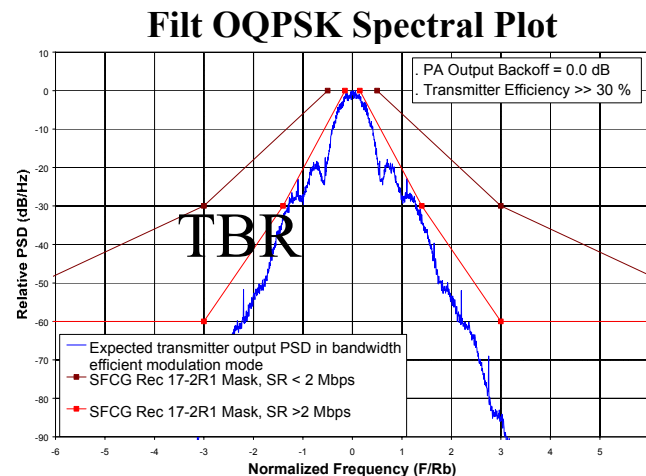
### KaTP Ground Segment Technology Insertion Support



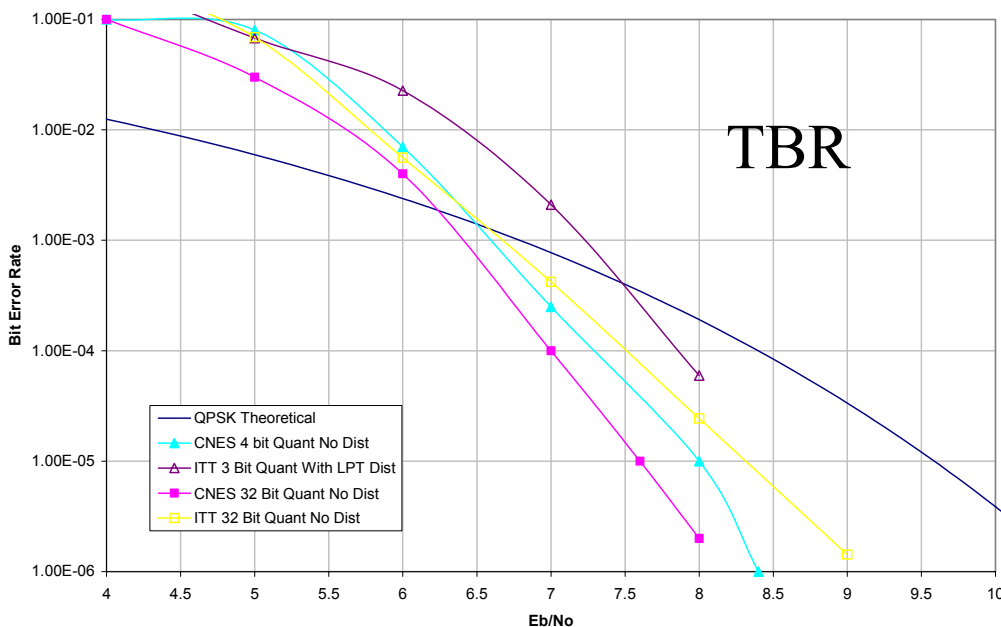


# Tracking & Data Acquisition Future Systems Applications Advanced Bandwidth Efficient Modulation and Coding Techniques Evaluation for Ka-Band Communications

- Under the BW Efficient Modulation Subtask, a simulation study to characterize the PSD and BER performance of 4 Dimensional 8 PSK TCM and Baseband Filtered OQPSK is being conducted
- These modulations are the most likely candidates to be selected by CCSDS as standards for use in the 26 GHz band



Multidimensional 8 PSK TCM BER Performance



- Preliminary analyses focus on implementation of these mod's at low rates in the (S-band) GSFC/ITT Low Power Xceiver (LPT) for future demonstration of concept testing

LPT Transceiver



# Tracking & Data Acquisition Future Systems Applications

## Ka-Band Component Technology WWW Database

- An online database (<http://classwww.gsfc.nasa.gov/kaband/>) documenting the results of Ka-band component technology surveys, including products developed by commercial and government entities
- Includes relevant specifications, performance data, cost, schedule, and contact information
- The online database provides a forum for the exchange of information about mission requirements, manufacturer capabilities that will promote the development of a variety of COTS products for future NASA use

### Database Reports Menu

<b><u>Table View Component Report</u></b>			Tabular Report of submitted and approved Components
Coders, Decoders, and Codecs	▼	Run Report	
<b><u>Individual Page Component Report</u></b>			Report by Component of submitted and approved components
Phased Array Antennas	▼	Run Report	
<b><u>Table View Mission Report</u></b>			Tabular Report of submitted mission data
SSPAs / TWTAs	▼	Run Report	
<b><u>Individual Page Mission Report</u></b>			Report by Mission of Submitted Mission data
High Rate Receivers	▼	Run Report	
<b><u>Table View Website Report</u></b>			Tabular Report of submitted and approved WebSites
Low Noise Amplifiers	▼	Run Report	

# Tracking & Data Acquisition Future Systems Applications

## Accomplishments

- **FY01 Accomplishments:**

- 9/01: Paper titled “NASA Ka-Band Transition Systems for Near Earth Communications--Capabilities and Demonstrations” was presented to the 7<sup>th</sup> Annual Ka-band Utilization Conference
- 09/01: Prepared paper titled “NASA Ka-band Developments and Capabilities for TTC Support to Near Earth Spacecraft” which will be presented to the 2<sup>nd</sup> Annual ESA TTC Conference in 10/01
- 9/01: Performed detailed simulation analysis of advanced bandwidth efficient 4 Dimensional 8 PSK TCM modulation/coding technique to evaluate its performance as it would be implemented in the GSFC/ITT Low Power Transceiver
- 9/01: Performed update to the online Ka-band technology database

- **Impact to Date:**

- Additional critical technology options and associated cost / availability data will be made available for the NASA / GSFC Ka-Band Transition Project
- The Ka-Band WWW Page continues to be heavily utilized by users both within NASA and industry
  - Average of over 350 hits per year

# Tracking & Data Acquisition Future Systems Applications

## Accomplishments / Plans

- **FY01 Plan vs. Actual Deviations: Modeling and BER performance simulation of the HRUPAA deferred due to lack of available data**
- **FY02 Planned Accomplishments (contingent upon funding):**
  - Continue to provide Ka-band technology support to the KaTP including the evaluation of industry RFI responses and the support for and documentation of high rate demonstration tests within the SN and GN
  - Future updates to the Ka-Band technology database to include additional Ka-band ground station and space qualified components identified through ongoing research and vendor contact

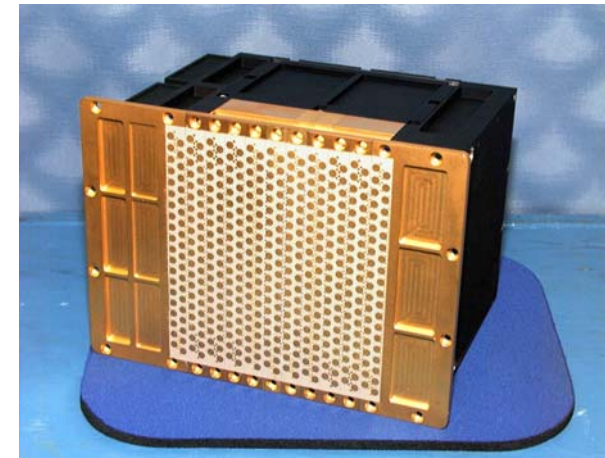
# Tracking & Data Acquisition Future Systems Applications

## Accomplishments / Plans

- **FY03 Proposed Activities (contingent upon funding):**
  - **Continued evaluation of advanced Ka-band communications efficient modulation and coding technologies through:**
    - **Analysis and simulation studies to support implementation of advanced GSFC standard efficient modulation techniques for Ka-band (e.g. Baseband Filtered OQPSK, 8 PSK TCM) in existing / planned Ka-band transceivers**
    - **Implementation of 4D 8PSK TCM capability in LPT transceiver and testing at S-band**
  - **Additional updates to the Ka-Band technology database**
  - **Additional KaTP documentation and follow-on support as required**
  - **Detailed IMDC-like communications systems engineering analyses for classes of future potential Ka-band GSFC missions (see below)**

# Tracking & Data Acquisition Future Systems Applications Ka-band Representative User Systems Engineering Study FY 03 Proposed Activity

- To encourage the transition of future NASA missions to Ka-band, a series of studies will be conducted to perform top level design and systems engineering, performance analysis and risk assessment for a set of future “fictional” spacecraft
- To meet the out-of-band emissions requirements for high rate space-to-Earth transmissions, these spacecraft will utilize BW Efficient Modulations such as Baseband Filtered OQPSK and 8 PSK TCM
- 3 fictional spacecraft will be designed based on composite requirements of existing and future missions:
  - High rate LEO Mission based on EOS/NPOESS
  - Medium Rate LEO/Suborbital Mission based on SOFIA, etc.
  - Medium-High Rate L1/L2 User based on ARISE, etc.
- Top level designs will be based on previously-developed reference architectures
- Systems Engineering analyses will be conducted to estimate E-E communication system requirements
  - Work with IMDC to utilize standard techniques?
- Final hypothetical design will include actual existing COTS/GOTS components from database where available, approximations thereof where not
  - Example – use HRUPAA for Medium Rate LEO / Suborbital Mission



# **Tracking & Data Acquisition Future Systems Applications Ka-band Representative User Systems Engineering Study FY 03 Proposed Activity**

- **Simulation models will then be developed for each of the components in the communication systems**
  - **Models based on data to be collected from vendors, etc.**
  - **Component models to be developed initially in SPW and integrated into existing end-to-end TDRSS and Direct-to-Ground system models**
  - **Simulations to be performed to assess implementation loss, PSD emissions, filtering requirements**
  - **Alternative BW Efficient Modulations to be compared**
- **Implementation loss will be combined with data throughput reliability requirements, mission orbital characteristics, likely ground station locations, and rain fade statistics to validate and refine spacecraft designs**
- **End results of the study will include:**
  - **Refined high level spacecraft and ground station communication system architectures which are compatible with the science requirements of future NASA missions and demonstrated to be feasible to implement at Ka-band**
  - **Cost estimates and risk factors for Ka-band implementations**
  - **Anticipated PSD and BER performance analysis results**
  - **Component-level simulation models in SPW, which can be transitioned to MATLAB/Simulink and made available on the Ka-band Component Technology Web Page to facilitate missions performing their own analyses**